High Efficiency and Long Lifetime for Organic Light-Emitting Diode Using a New Electron Transport Material

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Abstract

We demonstrated high power efficiency and long lifetime for organic light-emitting diode (OLED) using a new electron transport material (ETM-1). A power efficiency of the device with ETM-1 was improved compared to a standard device using tris(8-hydroxy-quinolinate)aluminum (Alq_3). Moreover, the lifetime was 4 times longer than the standard device.

1. Introduction

OLED technology has been rapidly developed and being put into several practical uses [1]. However, it does not satisfy completely an industrial demand for the efficiency and working stability, which are to be improved toward the commercialization. We chose ETM as the key substrate to achieve the high performance of OLED, because little attention has been paid on ETM less than HTM [2,3]. In this presentation, we would show the relative contributions of newly synthesized ETM to both power efficiency and lifetime on green OLED device.

2. Experimental

ETM-1 was synthesized by conventional process, and highly purified by train-sublimation.

The highest occupied molecular orbital (HOMO) level of ETM-1 was measured with the photoelectron emission spectrometer (AC-3, Riken Keiki). The lowest unoccupied molecular orbital (LUMO) level was estimated with the optical bandgap obtained from the onset of the absorption spectra.

Several devices were fabricated to evaluate the properties of ETM-1 as following; the 25 × 25 mm glass substrates coated with indium tin oxide (ITO) with a sheet resistance of 20 $\Omega \cdot sq^{-1}$ as the anode, were sequentially ultrasonicated in a commercial detergent and rinsed in ultrapure water. The substrates were exposed to an UV/ozone for 30 min before the vacuum deposition of organic materials. The devices were hermetically packaged in a dry nitrogen glove box with <1 ppm oxygen and moisture concentration.

The current-voltage characteristics and the EL luminance were measured using a KEITHLEY Inc. source meter 4ZA4 and a Topcon Inc. luminance meter BM-9. The operational lifetime characteristics were determined at 20 mA/cm^2 DC driving condition. The electron mobility of ETM-1 was measured by time-of-flight technique.

3. Results and Discussion

Table 1 shows thermal and physical properties of ETM-1 and Alq_3. Glass transition temperature (T_g) of ETM-1 was not detected on differential scanning calorimetry (DSC) analysis. We gave ETM-1 larger HOMO-LUMO gap compared with Alq_3. That could confine undesired energy transfer from emissive layer to electron transport layer and improve the efficiency of the device.

Table 1. Properties of the electron transport materials

		ETM-1	Alq_3
T_g	(°C)	N.D.	175
T_m	(°C)	327	413
LUMO	(eV)	-2.7	-3.0
HOMO	(eV)	-6.2	-5.8
PL film	(nm)	411	515

The electrochemical properties were studied by cyclic voltammetry in THF containing n-Bu_4NBF_4 (0.1 M) with a scan rate of 100 mV/s. As shown in Figure 1, ETM-1 exhibits a reversible one-electron reduction process, and no significant change in the

CV curves was observed in the range from -2.6 to 0 V even after multiscan (20 cycles). This result indicates ETM-1 has excellent electrochemical stability against cathodic reduction.

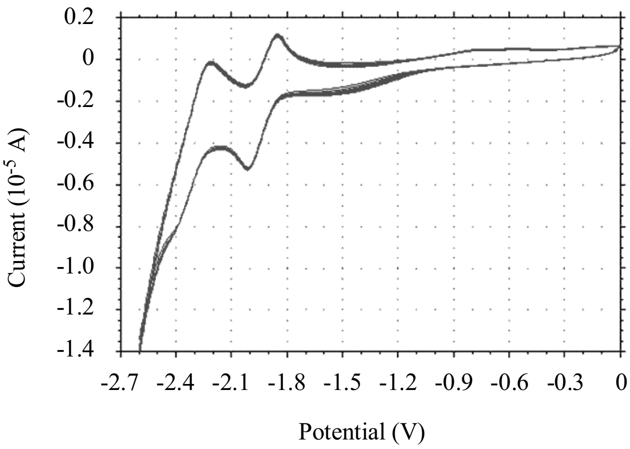

Fig. 1. Cyclic voltammograms of ETM-1

For mobility measurement, we fabricated a device which was comprised of [ITO/ETM-1 (2 μm)/Al (100 nm)]. The electron mobility of ETM-1, which estimated from the intersection of the transit photocurrent profile, was 3.8×10^{-5} cm^2/Vs at electric field 400 $(V/cm)^{1/2}$. Figure 2 shows the electric field dependence of the electron mobility. The electron mobility of ETM-1 is approximately 10 times higher than that of Alq_3 [4] at each electric field.

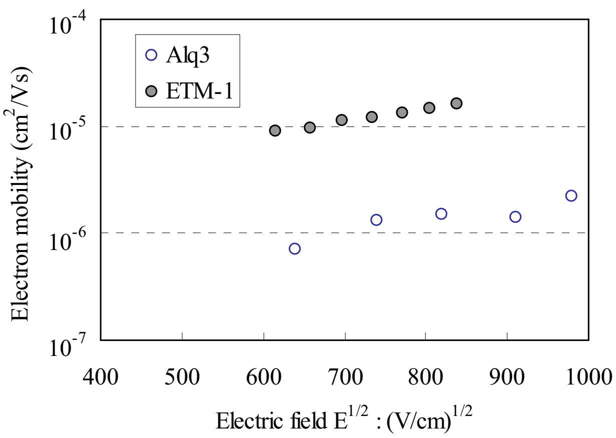

Fig. 2. Electric field dependence of electron mobility

We fabricated green OLED devices which were comprised of [ITO/CuPc (25 nm)/NPD (45 nm)/Alq_3 (40 nm)/Alq_3 or ETM-1 (20 nm)/LiF (1 nm)/Al (100 nm)]. *J-V* characteristics of the devices were shown in Figure 3. The driving voltage (defined as the voltage required to give a current density of 100 mA/cm^2) of the device with ETM-1 was significantly reduced to 5.2 V, which was smaller than that of the standard device using Alq_3 by 2.6 V. Higher carrier mobility of ETM-1 would contribute to the reduction of the driving voltage.

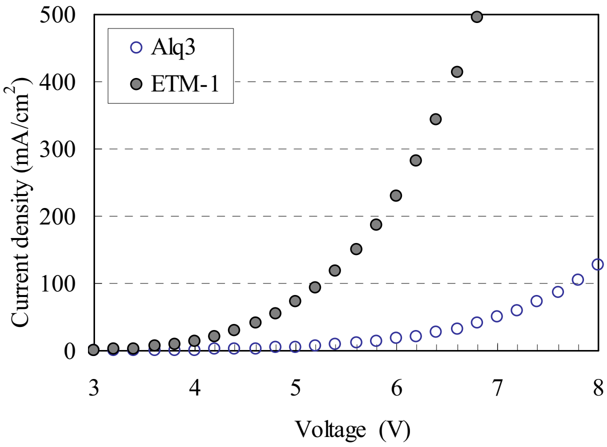

Fig. 3. *J-V* characteristics of the devices

Figure 4 shows power efficiency of the devices. Reducing the driving voltage, the power efficiency with ETM-1 increased to 3.1 lm/W at 10 mA/cm^2, while 2.6 lm/W was obtained from the standard device. It should be noted that the device with ETM-1 keeps high power efficiency even in high current density region. Low HOMO level of ETM-1 would allow itself to act as a hole blocking layer raising power efficiency.

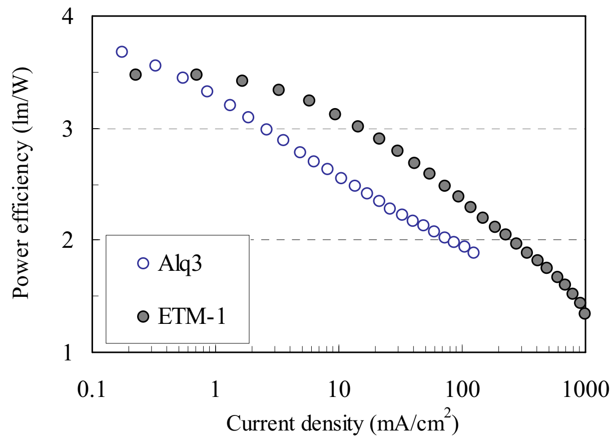

Fig. 4. Power efficiency of the devices

The lifetime evaluations of the devices were conducted at current density of 20 mA/cm^2. Figure 5 and 6 show *luminance-time* and *voltage-time* characteristics, respectively. The half-luminance lifetime of the device using ETM-1 was more than 4 times as long as that of Alq_3, and reached 4300 hours.

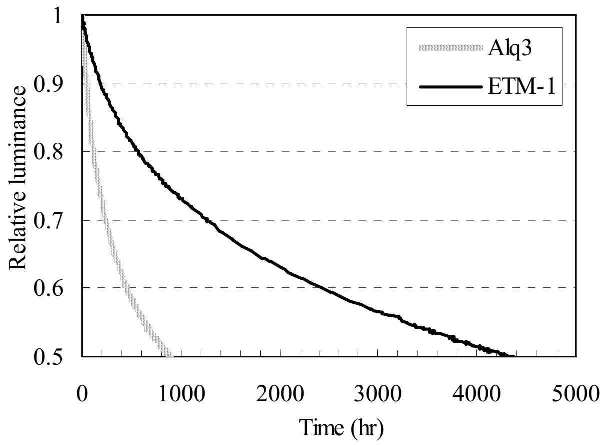

Fig. 5. Lifetime of the devices at 20 mA/cm^2

The operating voltage with ETM-1 slightly increased by 0.7 V after 1000 hours, while 1.5 V for the standard device. We consider that the good working stability was due to electron resistance of ETM-1. Thus, ETM-1 would provide advantages on the power consumption and long-term operational stability when it would be utilized in OLED displays as commercial products.

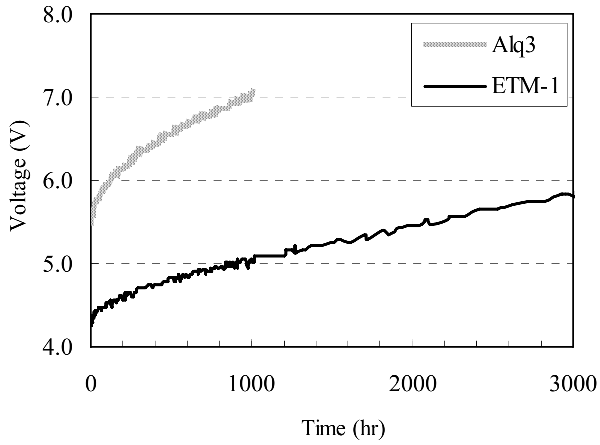

Fig. 6. Voltage rising of the devices at 20 mA/cm^2

4. Summary

We found the relationship between the material properties and OLED performances and achieved the improvements both power consumption and lifetime on the electroluminescent device with the new ETM.

5. References

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